Acta Archaeologica Academiae Scientiarum Hungaricae Tomus XII, Akadémiai Kiadó, Budapest (1960), pp. 82-111.
(24) Stuart Piggott, The beginnings of wheeled transport, Scientific American, *219*, 82 (1968).
(25) O. Menghin, Weltgeschichte der Steinzeit, Wien (1931).
(26) P. Aalto, Ein alter Name des Kupfers, Ural-Altaische Jahrbücher, *31*, 33 (1959).
(27) Martin Gardner, Counting systems and the relationship between numbers and the real world, Scientific American, *219*, 218 (1968).
(28) Jacquetta Hawkes and Leonard Woolley, History of Mankind, Vol. 1, Harper and Row, N.Y. and Evanston (1963).

Action to Avert the Population-Food Crisis

Archibald T. McPherson

4005 Cleveland Street, Kensington, Maryland

The impending collision between population and food supply has been termed "the biggest, most fundamental, and most nearly insoluble problem that has ever confronted the human race" (1). It transcends all other problems of our day in urgency and in potential effect on the future of the world.

That the present increase in population must be checked, almost all are agreed. At best, however, this will require time—certainly until 1985 and perhaps until the year 2000. Thus, the immediate problem is to increase the food supply so that the population explosion can be brought under control in an orderly manner and not through mass starvation or through a breakdown of the social order that might even precede widespread starvation.

For the years immediately ahead, some foresee only famine spreading to one after the other of the developing countries. Others voice cautious optimism that global famine can be averted if a sufficiently massive effort is exerted without delay. Still others see a green revolution in agriculture in the making that will, at least, maintain the admittedly inadequate standards of nutrition in the developing countries in the coming critical years.

In this paper we shall examine some of these seemingly disparate points of view as presented in three recent books, and, from what these authors and others say, we shall set down some factors that may determine whether or not catastrophe can be avoided. The deficits in the world food supply are large and varied. We shall mention some of the most critical needs in the developing countries and means of meeting them. In conclusion we shall address ourselves to constructive actions that scientists may take in doing their part to meet the emergency.

Statistics regarding the world population-food problem have been so widely publicized that there is need here only to present a few figures emphasizing the wide and growing gap between the industrially developed and the developing countries. Table 1 summarizes the differences between the "have" and the "have not" countries in population, population growth, food supply, income, literacy, and proportion of children below the age of self-support. Data for five countries—the United States, Japan, Brazil, India, and Nigeria—are given in Table 2. In these countries the *per capita* annual income ranges from $2898 to $63, and the illitera-

Table 1. The Gap Between the 'Have' and the 'Have-not' Regions of the World

Item	Industrially Developed Regions	Underdeveloped and Developing Regions
Location	Temperate zone North America, Europe, and Oceania. Also U.S.S.R., Japan, South Africa, and Argentina	Largely in tropics Most of Africa, Asia, and Latin America
Population, millions:		
Mid-1968	1,081	2,400
1980, estimated	1,215	3,200
Gain, 1968-1980, percent	12½	33
Annual income, *per capita*, dollars	1,332	125
Food supply, calories per person per day	3,000	2,200
Population illiterate, 15 years of age and over, percent	4	58
Population under 15 years of age, percent	28	41

Table 2. Facts About Five Countries

Item	United States	Japan	Brazil	India	Nigeria
Population, 1968, millions	201	101	88	523	62
Rate of growth, percent per year	1.1	1.1	3.2	2.5	2.5
Years to double	63	63	22	28	28
Birth rate per 1000 population	18.5	13.7	41–43	41	45–53
Death rate per 1000 population	9.5	6.8	10–12	18	25–32
Infant mortality per 1000 live births, first year	22.9	18.5	—	140	—
Annual income, *per capita*, dollars	2893.	696	217	86	63
Food supply, calories per person per day	3140	2350	2950	2110	2180
Population illiterate, 15 years and over, percent	0–3	0–2	30–35	70–75	80–88

cy from near zero to 80 to 88 percent.

A convenient summary of information regarding the population of the world by countries, regions, and continents is given in the World Population Data Sheet of the Population Reference Bureau (2). Detailed information regarding the world food supply is to be found in publications of the Food and Agriculture Organization of the United Nations, particularly in the annual report on the State of Food and Agriculture, and in the Production Yearbook (3).

I. Three Views of the Future

Three recent books have been selected to illustrate the divergence in forecasts as to the course of events in the next one or two decades. These books are by well qualified, widely recognized authors who have made first-hand observations in the developing countries and have drawn on the very extensive statistical and other information now available regarding trends in population and food supply. The principal differences, we shall see, lie in differences in estimates as to what people can and will do to meet the coming emergency.

The three books are:

William and Paul Paddock, "Famine 1975. America's Decision: Who Will Survive?", Little, Brown & Co., Boston, 1967.

Orville L. Freeman, Secretary of Agriculture, "World Without Hunger." Frederick A. Praeger, New York, 1968.

Max F. Millikan and David Hapgood, "No Easy Harvest." Little, Brown & Co., Boston, 1967.

As may be inferred from the titles, the Paddock brothers and Secretary Freeman are at the extremes of pessimism and optimism, respectively, with Millikan and Hapgood in an intermediate position. All three regard the next one or two decades as critical.

1. Catastrophe Is Inevitable. "Famine 1975" was written on the basis of the Paddock brothers' long experience abroad, one in the Foreign Service of the State Department, and the other in agricultural research, teaching, and administration. Their view of the world situation is stated in the title of the first chapter—"The Population-Food Collision Is Inevitable; It Is Foredoomed." This graphic analogy is presented:

"A locomotive is roaring full throttle down the track. Just around the bend an impenetrable mudslide has oozed across the tracks. There it lies, inert, static, deadly. Nothing can stop the locomotive in time. Collision is inevitable. Miles up the track the locomotive could have been warned and stopped. Years ago the mudsoaked hill could have been shored up to forestall the landslide. Now it is too late.

"The locomotive roaring straight at us is the population explosion. The unmoveable landslide across the tracks is the stagnant production of food in the undeveloped nations, the nations where the population increases are greatest.

"The collision is inevitable. The famines are inevitable."

The Paddocks' book proceeds to show that the time will be too short for the underdeveloped nations to bring up their productivity, and that the United States and other Western nations cannot continue to make up the food deficit because the numbers of people to be fed will soon be too great.

The proposal is made that, in time of widespread famine, the United States institute "triage" in allocating its food aid to the developing nations. Triage is the practice followed by hospitals on the battlefield when the number of wounded exceeds the capacity to treat them. The casualties are divided into three groups: those that could not be saved; those that would survive without treatment; and those that could be saved by treatment. The third group would receive the limited attention that could be given.

In applying triage to countries under global famine conditions, the maximum amount of food that the United States could export would go to selected countries that could be saved. Certain other countries would be able to get through the time of famine by their own efforts, though with difficulty. A third group of countries would have to be cut off because, with all that could be done, it would be impossible to save them.

In the concluding chapter the authors call on the United States to accept responsibility and leadership, and take the difficult but necessary action. The title of the chapter is "The Time of Famines Can Be the Catalyst for a Period of American Greatness." The book ends with a section headed, "Now It Is America's Turn to Shape History."

2. The Problem Can Be Solved. "World Without Hunger" by Freeman is described on the jacket as "an eloquent, practical guide to solving man's ancient problem of how to achieve a world without hunger." The concluding paragraph of the preface states further:

"This book seeks to explore what you and I can do as individuals and what our nation and other nations must do as governments to free mankind from the threat of famine. It is written out of my conviction that, if all peoples work together, nightmares of starvation can be forgotten and we can realize the age-old sweet dream of a world without hunger."

In the book Freeman deals with some of the major complex and interrelated problems involved in augmenting the world food supply. Attention is directed to the number and variety of resources that must be drawn upon in solving the problems. Success stories used for illustrations contribute to the optimistic outlook, but the author admits that the achievements of the past 20 years of American aid have been inadequate in the face of total need. He says (p. 175) "We have expected to accomplish too much in too short a period with too little effort." He states further,—

> "We have made other mistakes. The keys to sound development—family planning, agriculture, and education—were neglected until recently. We underestimated the obstacles and overestimated the transferability of technology. We promised more than we could deliver, sometimes starting a chain reaction of disillusionment and distrust, which has increased the difficulty of development."

In conclusion, Freeman urges United States leadership directed toward four specific goals: (1) the establishment of long range nutrition targets and particularly the redirection of food aid toward eliminating malnutrition in children; (2) a ten-year commitment of 1.5 percent of the United States national income to development, with emphasis on food production; (3) the creation of a private-public corporation, perhaps patterned after Comsat, to deal with agricultural problems; and (4) the speedy mobilization of a wide range of technical manpower.

As to the future, Freeman states: "The road ahead is long and hard. The sands of time are running fast. We have no more than fifteen to twenty years to bring man and his food supply into balance." He makes no prediction as to whether the program that is proposed can and will be implemented fully and quickly enough to achieve the balance before time runs out.

3. A Gigantic Effort Will Be Required. "No Easy Harvest" by Millikan and Hapgood is in large part a product of the deliberations and conclusions of a six-week conference by 44 experts at Massachusetts Institute of Technology's Center for International Studies in the summer of 1964. The 44 persons are described as "scholars and practitioners, eminent in economics, natural sciences, the behavioral sciences, and the political sciences."

An important contribution made by the book is its emphasis on the need for an interdisciplinary approach to the problems of agriculture as a source of food. Millikan and Hapgood state in the introduction, ". . . the burden of our message is precisely that the agricultural problem is not divisible. . . . The book is a whole, not the sum of its parts."

Emphasis is placed on the importance of recognizing differences in local conditions. Specific attention is given to four different food-deficit regions: the Rice Regions; the Rain-Forest Tropics; the Monsoon Regions and the Sub-Tropics; and the High Altitude Regions.

Far from purporting to have developed a guide for solving the problem of hunger, Millikan and Hapgood evaluate their book in the following terms:

> "We offer no panacea here. Those looking for a blueprint will be disappointed. We did not find a magic key to unlock the problems of agriculture, nor do we present a program likely, in ten years or a century, to assure the world's supply of food."
>
> "Finally, ours is not a cheerful report. Compared to the urgency of the need, what we offer here may seem meagre indeed. . . . To get the people of the world a decent supply of food—that most basic of man's requirements—will require a gigantic effort. It will cost a lot of money, but money is probably the easiest need to fill. The goal will not be met unless many millions of people—technicians, officials, and, above all, farmers—are willing to initiate a radical and often painful process of social change."

II. There Is Hope, if—

The foregoing authors and others who have written or spoken on the population-food problem are in agreement that the present rate of population growth must be checked as quickly as possible so as to bring the population into balance with the food supply. Most of them would probably agree, also, that widespread famine could be averted by a sufficiently early and sufficiently massive effort. They would disagree, however, as to the probability that such an effort will be made. As one author put it, "The question is not, 'Can we?,' but 'Will we?' " Thus, the future increase in food supply will depend in large measure on the magnitude of human effort. This will involve a number of different factors, some of which will be discussed in the following paragraphs. In addition, one significant factor in determining food supply, the weather, will be beyond human control except insofar as irrigation can be extended to mitigate the effect of drought.

1. If Weather Is Favorable. Projections as to crop yields are necessarily based on a number of assumptions. The first is usually "normal weather," meaning adequate rainfall, and the absence of destructive floods, winds, hail, and unseasonable cold or heat. In "World Food Budget 1970" (4) the assumption of normal weather is qualified as "probably more favorable than a statistical average." Abundant rains in India have been a significant factor in the increase in grain production in the past two years. This increase has given hope of self-sufficiency in food production in the near future, but failure of the monsoons could again lead to misery and dispair, as in 1964 and 1965. The food supply in Mainland China, the Middle East, and North Africa is dependent to a very considerable extent on rainfall so that any time table of famine could be set ahead or delayed by the weather.

2. If Existing Foods Are Used Most Efficiently. The diet in the developing countries is often inadequate for growth, yet the grains, pulses, and oilseeds consumed in these countries contain significant percentages of protein. The vegetable proteins, however, can be only partially utilized in human nutrition because they do not contain essential amino acids in the proportion required by the body. They can be employed for growth or maintenance only to the extent that the most limiting amino acid is present—which may be only 50 percent or less. This deficiency can be corrected by adding the requisite amount of the limiting amino acid or acids, which are now produced synthetically at costs which would render their large-scale use entirely feasible. At present the amino acid supplementation of wheat and wheat products is being practiced on a limited scale in India and a few other developing countries. Whether such supplementation will be expanded and extended to other staple grains is yet to be determined.

It is a fortunate circumstance that the amino acid deficiencies in vegetable proteins are such that the proteins of cereal grains and oilseeds are, to a considerable extent, mutually complementary. Thus, neither corn nor cottonseed flour, taken alone, is adequate to support the growth of children, but a mixture of the two is the basis of Incaparina, a prepared food that is being used successfully to combat childhood malnutrition in Latin America. A number of other general purpose and multipurpose foods have been devised in different developing countries by blending locally available grains, pulses, and oilseeds in proportions such as to give an optimum amino acid pattern for human nutrition. Vitamins and minerals needed in the diet are routinely added to these prepared foods. The success of these foods has been abundantly demonstrated, but their production is still relatively small in comparison to the supply of food for children in developing countries.

3. If Non-agricultural Sources of Food Are Fully Exploited. Several sources of food other than conventional agriculture can contribute significantly to the world food supply and offer the advantages of rapidly expanded and controlled production, together with freedom from the effects of weather, diseases, and insect pests. One such source is protein concentrate made from fish that are not now used for human food. The potential production is large, but at best it will be considerably less than the supply of protein from agricultural sources.

Another potential source of food which has been widely publicized is the production of microorganisms from petroleum and other substrates. Primary attention is being given to yeast and other organisms as a source of protein, though fat can be produced in a similar manner by the culture of different organisms. All of the major petroleum companies are engaged in this development and the world capacity for microbial protein may reach a million tons a year by 1970 (5). The product is now intended for animal feed, though its ultimate use for human food is undoubtedly the objective of the present intensive research and development.

The culture of tissues, both plant and animal, has long been practiced in the research laboratory. Animal tissues of different kinds have been grown in nutrient media of relatively simple composition, but the techniques are quite elaborate, requiring strict asepsis and precise control of all conditions. In recent years, however, engineering processes have been developed with automated controls, that could render it possible to manufacture animal protein for use as food without the intervention of the animal.

Another source of food of large potential significance is production by direct chemical synthesis. It is surprising that this has received so little attention from the chemical industry in view of the fact that every important non-food agricultural product except tobacco has one or more commercially successful synthetic counterparts. At present the principal synthetic products in this area are vitamins, flavors and condiments, and amino acids. Large quantities of the vitamins and amino acids are employed in animal feeding in competition with an abundance of feed from agricultural sources.

4. If There Is General Economic Development. Increased agricultural productivity and improved nutrition can be achieved only if there is corresponding economic growth and rising *per capita* income. Agriculture, by the primitive methods now employed in large areas of the developing countries, can produce only a little more food than that required by the farmer and his draft animals. More productive agriculture will require large inputs of equipment, improved seeds, pesticides, and fertilizer, all of which must be supplied by the rest of the economy. Furthermore, the increases in food production brought about by these inputs can be sustained only if the income of the non-agricultural segment of the population is raised sufficiently to buy the additional food. To achieve the requisite over-all economic development in a very few years will require massive support from the United States and other affluent nations in the form of capital and technical assistance.

5. If the "Green Revolution" Continues. Recent signal developments in agriculture have been quite aptly termed the "Green Revolution." Three advances that have received wide attention are Mexican wheat, high-lysine corn, and "miracle" rice. The wheat and the rice give promise of much higher yields while the high-lysine corn should greatly improve the nutrition of both man and animal by providing protein that possesses an amino acid pattern which will permit it to be much more fully utilized than the protein of conventional varieties.

The successful application of these advances in the different developing countries will involve many problems, not the least of which will be a large expansion in the production and use of fertilizer. The miracle rice, for example, yields little if any more than conventional varieties under the same conditions. The sensational increases in yield are obtained only with the liberal use of fertilizer, and the production of the necessary fertilizer will require time, technical assistance, and capital.

There is danger that success stories regarding these new advances will generate an unwarranted optimism regarding the future. Agricultural production of food can be markedly increased but it cannot long keep pace with an exponential growth of population. The best that can be hoped for from the Green Revolution and other means of increasing the food supply of the developing countries is that they will buy more time in which to bring the population explosion under control.

III. Critical Food Needs

In the present shortage of food in developing countries it is important to know just where the major deficiencies lie so as to direct the limited supplies and research efforts to meeting the most acute needs. It is also important to make long range plans so as to achieve the maximum nutritional benefit. The new science of nutrition can provide valuable guidance both in the allocation of food supplies and in the planning of new production. It is strange that food —the oldest concern of man—has only so lately become the subject of extensive scientific investigation. Food for children has been a concern of parents from the beginning of the human race, but only within the present decade has there been clear recognition and documentation of the relation of protein in the diet of the young child to its mental development and the mental as well as the physical characteristics of the adult into which the child develops.

In addition to this special need for adequate protein for child development we shall discuss briefly the related need for vitamins and minerals, and the general need for food to supply additional calories in the diet of the developing countries.

1. Protein for the Growth of Children. The most important single action that can be taken to aid the developing countries is to provide protein, adequate in quality and quantity, to support the growth of children between the time of weaning and the age of four or five. Proper nutrition in this period leads to alert, intelligent, and responsive adults; lack of it, to dull, apathetic adults, little interested in bettering their lot. A recent book on this subject bears the title, "Pre-School Child Malnutrition. Primary Deterrent to Human Progress" (6). Some of the distressing findings reported in this book are:

"Pre-school malnutrition is basically responsible for the early deaths of millions of children.

"Of those it does not kill, preschool malnutrition permanently impairs physical growth and probably causes irreversible mental and emotional damage;

"Preschool malnutrition is a serious deterrent to progress in developing countries; it weakens the productive capacities of adults surviving from the irreparable damages incurred in early childhood.

"In developing areas, as many as 70 percent of the children suffer from malnutrition. The maimed survivors become adults lacking in the vigor and enterprise for productive advancement."

In the affluent Western countries the protein needs of children are met, for the most part, by milk, meat, and eggs. These, however, are scarce in developing countries and are probably the least available to those that need them most. However, as mentioned in an earlier paragraph, present knowledge of the amino acid content of foods renders it possible to make mixtures of locally available cereals, pulses, and oilseed meals that are nutritionally adequate for child growth.

Inasmuch as prepared foods designed to meet the protein needs of young children are now available in most developing countries, the major problem is one of securing acceptance and providing for distribution to those segments of the population that cannot afford even the small additional cost. General acceptance will involve the slow and difficult process of educating largely illiterate populations who have deeply ingrained prejudices and superstitions regarding food and nutrition.

2. Vitamins and Minerals. The addition of vitamins and minerals to the diet in the developing countries could make a very significant contribution to the health and well-being not only of the children but also of the population as a whole. Unlike the situation with regard to many other needs, the materials required to fill this need could be supplied in a relatively short time at low cost. Vitamins are now made synthetically by large scale production methods; hence production could be readily stepped up to any desired extent by the replication of present manufacturing units. The cost of supplying all the vitamins in the Recommended Dietary Allowances of the Food and Nutrition Board (7) would be only about 17 cents per person per year on the basis of the values of vitamins produced in the United States, as reported by the U.S. Tariff Commission (8). The materials cost of minerals such as calcium, magnesium, and iron would be nominal, and even the cost of iodine would be quite small because of the minute quantities required per person.

Of the vitamin deficiencies, the most tragic is the deficiency in Vitamin A which causes 80,000 children to become blind each year and leads to seriously impaired vision in a much greater number (9). The manufacturing cost of sufficient Vitamin A to supply a child for a year is only about 6 cents.

Goiter is readily prevented by traces of iodine in the diet, yet there are regions in which goiter is so prevalent that it is sometimes taken as a mark of feminine beauty and children's dolls are made with prominent goiters.

Anemia resulting from a deficiency of iron and copper in the diet is widely prevalent in the developing countries and may be responsible for the lack of vitality that is often ascribed to the tropical climate. Anemia and vitamin deficiencies taken together with a diet low in calories are undoubtedly responsible for the low productivity of labor that is so frustrating to those undertaking new programs in the developing countries.

The major problem with vitamin and mineral dietary supplements is that of getting them to the people that need them. In the United States certain of the essential micronutrients are incorporated in bread, other cereal products, margarine, milk, and fruit juices, thus insuring that some of the vitamins and minerals otherwise lacking in the diet will reach a considerable segment of the population. In the developing countries, however, much of the food does not go through central process and distributing channels, hence other means of distribution must be found. Brooke (13) has suggested admixing vitamins and minerals with salt so as to reach an entire population. He has also suggested, for voluntary use, a "pot pill" containing the daily supply of vitamins and minerals for a family. This would be added to the rice, vegetables, or curry being prepared for the main meal of the day. So far as is known, neither of these or any other distribution plan is in use or under serious consideration at the present time.

3. Calories for Doing Work. As stated in a previous paragraph, the productivity of labor depends in part on the number of calories provided by the food of the workers. This has been demonstrated by correlations between the output of labor in different countries and the amount of energy provided by the diet in those countries. In industrially developed countries each person consumes, on the average, about 3000 calories per day, whereas in the undeveloped countries the amount is only about 2000 calories. It is true that in the latter countries the stature and body weight are less, but more than offsetting this difference is the fact that in the undeveloped countries a large part of the energy for doing work must come from human muscular power, rather than from motors as in the West.

This gap in calories could be filled by synthetic fats or by other synthetic, high-energy foods that have been developed for space nutrition (10). Synthetic fats were used in Germany during World War II but were given up when the cheaper natural fats became available (11). Synthetic fatty acids are currently produced in considerable quantities for industrial use. The manufacture of fats for human food would involve no major technical problem, and the output could be stepped up rapidly. Acceptance would present no problems because the synthetic products would be quite similar to natural products in both composition and properties. Furthermore, fats are in demand in developing countries where cereal grains make up a very large part of the diet. Thus far, no comprehensive engineering study seems to have been made of processes and costs in connection with high energy foods.

IV. What Can the Individual Scientist and Engineer Do?

The population-food problem is so massive that the individual may think that only national and international effort can make any significant contribution to its solution. True, the United States, many other nations, and the United Nations, as well as many nongovernmental organizations are all engaged in pertinent activities. But the sum total of effort is still far too small and the scope is still too narrowly restricted.

The concerned individual who studies the world situation can find ways to build support for the programs of government, industry, universities, and foundations that are contributing effectively to the solution of world problems. Further, he can provide original ideas and take the lead in initiating programs in his own field of specialization, and, as opportunity develops, he can participate in these and other programs.

1. Be Informed. One can make an effective contribution to the solution of the population-food problem only after gaining an understanding of the many complex factors involved. Nearly every one can read and study the very extensive and rapidly growing volume of literature on the subject and attend some of the numerous symposia and conferences that are being held. First-hand knowledge can be gained by travel in the developing countries with arrangements to meet government officials, agricultural agents, doctors and nurses, teachers, Peace Corps workers, and missionaries. The informed person will discount quick, easy solutions of problems and will recognize the signal advances that are being made in agriculture in perspective as means of buying a little more time in which to bring population and food into balance.

2. Support Governmental and Other Programs. If the massive effort that the population-food problem will require for its solution is to be exerted, the United States must accept a position of leadership and must provide much more technical assistance and funds than at present. Scientists and engineers, through their better understanding of many aspects of the problem, can be of great assistance in keeping the public more fully and correctly informed. They can also aid by presenting the needs clearly and in perspective to legislators and other key officials who have the responsibility for government participation. They can, in addition, be helpful in encouraging participation by industry, universities, foundations, and scientific and engineering societies.

The Sierra Club has taken action through publication of a book, "The Population Bomb" (12). This book not only emphasizes the importance of contact with officials, but it also includes in an appendix copies of letters that have been written by members of the Club to members of Congress, dignitaries of churches, and officials of television networks.

3. Seek an Opportunity for Personal Participation. Some jobs both in the United States and abroad are seeking people. In the many ramifications of the world population-food problem there are a great many more jobs yet to be discovered, particularly in new and unconventional approaches to long-standing problems. There is scarcely a discipline, a specialty, or an interdisciplinary area in which there is not a substantial contribution to be made by a person of vision. As to time, there are challenging opportunities for a lifetime career, or for a sabbatical year in a developing country, or even for productive activity in the retirement years of a septuagenarian who is still fit.

In every major emergency the most significant and original contributions are made by those who find their own roles, rather than waiting to be recruited.

References

(1) Ewell, Raymond. Population outlook in developing countries, *In* Agricultural Research Institute, The Role of Agriculture in Meeting World Food Needs, p. 3. National Academy of Sciences—National Research Council, Washington, D.C. Oct. 10-11, 1966.

(2) Information Service, Population Reference Bureau, 1755 Massachusetts Ave., N.W., Washington, D.C.

(3) Food and Agriculture Organization, United Nations, Rome, Italy. Available in the United States from the National Agency for International Publications, 317 East 34th St., New York 10016.

(4) Foreign Agricultural Economic Report No. 19. U.S. Dept. Agriculture. Oct. 1964.

(5) Humphrey, Arthur E. Production of pro-

tein from petroleum. Western Hemisphere Nutrition Congress II. San Juan, Puerto Rico. Aug. 26-29, 1968.

(6) Publication 1282. National Academy of Sciences—National Research Council. Washington, D.C. 1966.

(7) Publication 1146. National Academy of Sciences—National Research Council. Washington, D.C. 1964.

(8) Synthetic Organic Chemicals. United States Production and Sales. 1966. Tariff Commission Publication 248. Superintendent of Documents, Government Printing Office, Washington, D.C. 1968.

(9) Schaefer, Arnold E. Epidemiological studies of Vitamin A deficiency. Western Hemisphere Nutrition Congress II. San Juan, Puerto Rico. Aug. 26-29, 1968.

(10) Miller, Sanford A. High energy nonfat nutrient sources. *In* Conference on Nutrition in Space and Related Waste Problems, pp. 343-351. Tampa, Florida. April 27-30, 1964. Publication SP-70. National Aeronautics and Space Administration. Washington, D.C. 1964.

(11) Sonntag, N. O. V. Synthetic fatty acids. *In* E. Scott Pattison, Fatty Acids and Their Industrial Applications. Marcel Dekker, Inc., New York. 1968.

(12) Ehrlich, Paul R. Ballantine Books, Inc. New York. 1968.

(13) Brooke, Clinton L. Fortification of food products with Vitamin A. Western Hemisphere Nutrition Congress II. San Juan, Puerto Rico. Aug. 26-29, 1968.

Chemical Opposites and Their Ambiguities

Eduard Farber

4530 Brandywine St., N.W., Washington, D. C.

Progress through Reversions

In life and in science, the separation of opposites can mean an important step in the right direction, a feat of quick intuition or the result of long investigation. Yet after the opposites have been sharply distinguished and defined, they may be recognized as variously related to each other.

When their relationship is only that of complete opposition involving contradiction, there is the possibility of complete reversion. The Copernican reversion from the geocentric to the heliocentric system is a great historical fact, and it can serve as the model or example for important events in the history of chemistry (1). Other historical examples show us the opposites combined and new unity created out of contradictions. Robert Grosseteste, or Greathead (1175-1253), defined light, which for him was the first form of corporality, as being a spiritual body or a bodily spirit ("corpus spiritualis, sive mavis dicere spiritus corporalis"). Paracelsus (1493-1541), whose great concern was the relationship between human body and spirit, proclaimed triumphantly: "The life of man is nothing else than an astralic balsam, a balsamic ingression, a heavenly and invincible fire." Poetic visions perceive the contradiction between opposites reconciled in a primary unity, which for Grosseteste is light, for Paracelsus life.

The wider the significance of the opposites, the greater the need to combine them in their unity. This rule seems to follow from the nature of opposites. When they are limited and specific, they cannot be so combined, and complete reversion is preferred, or rather specifically justified. Joseph Black performed such a reversion when he demonstrated that instead of the addition of an invisible, fiery principle, it